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The INSTITUTE Spokesman

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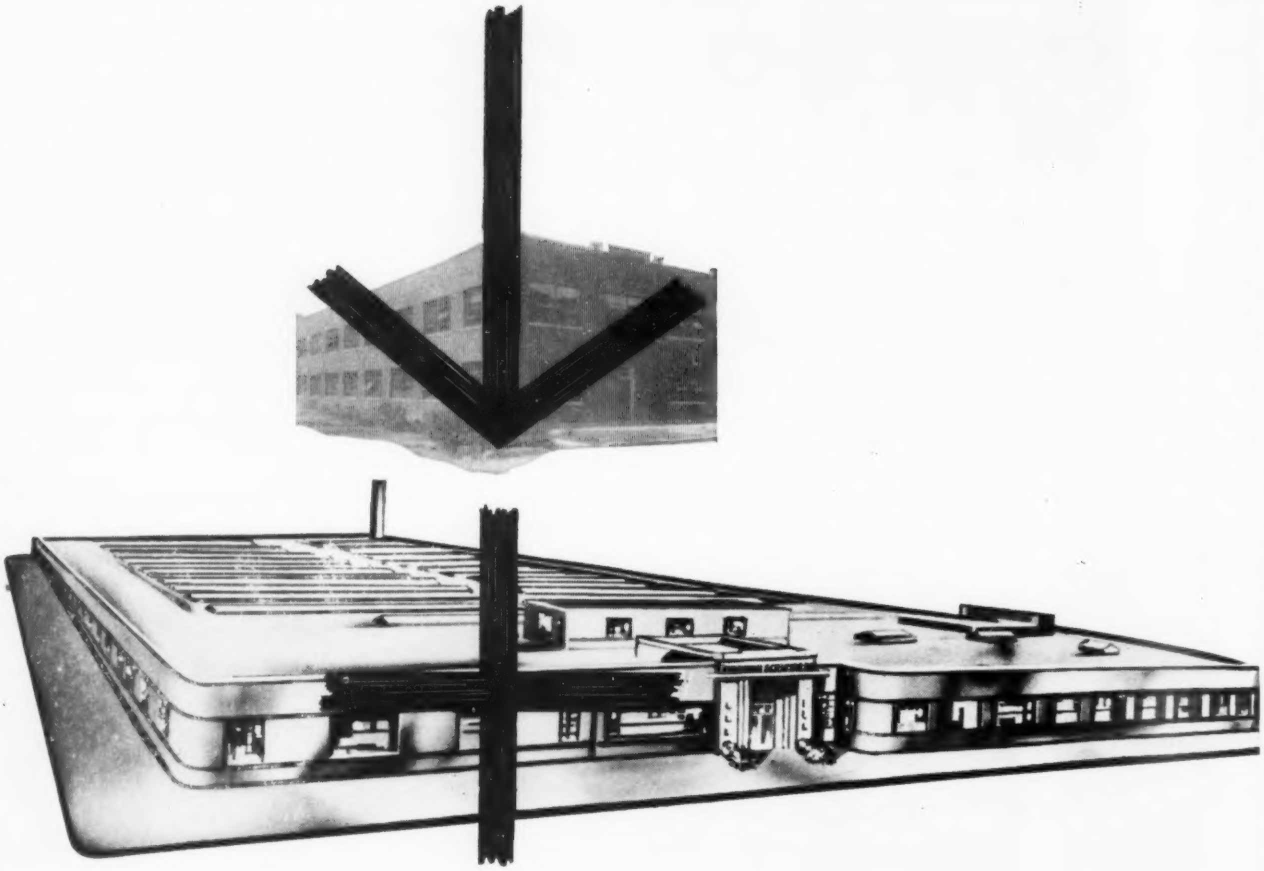

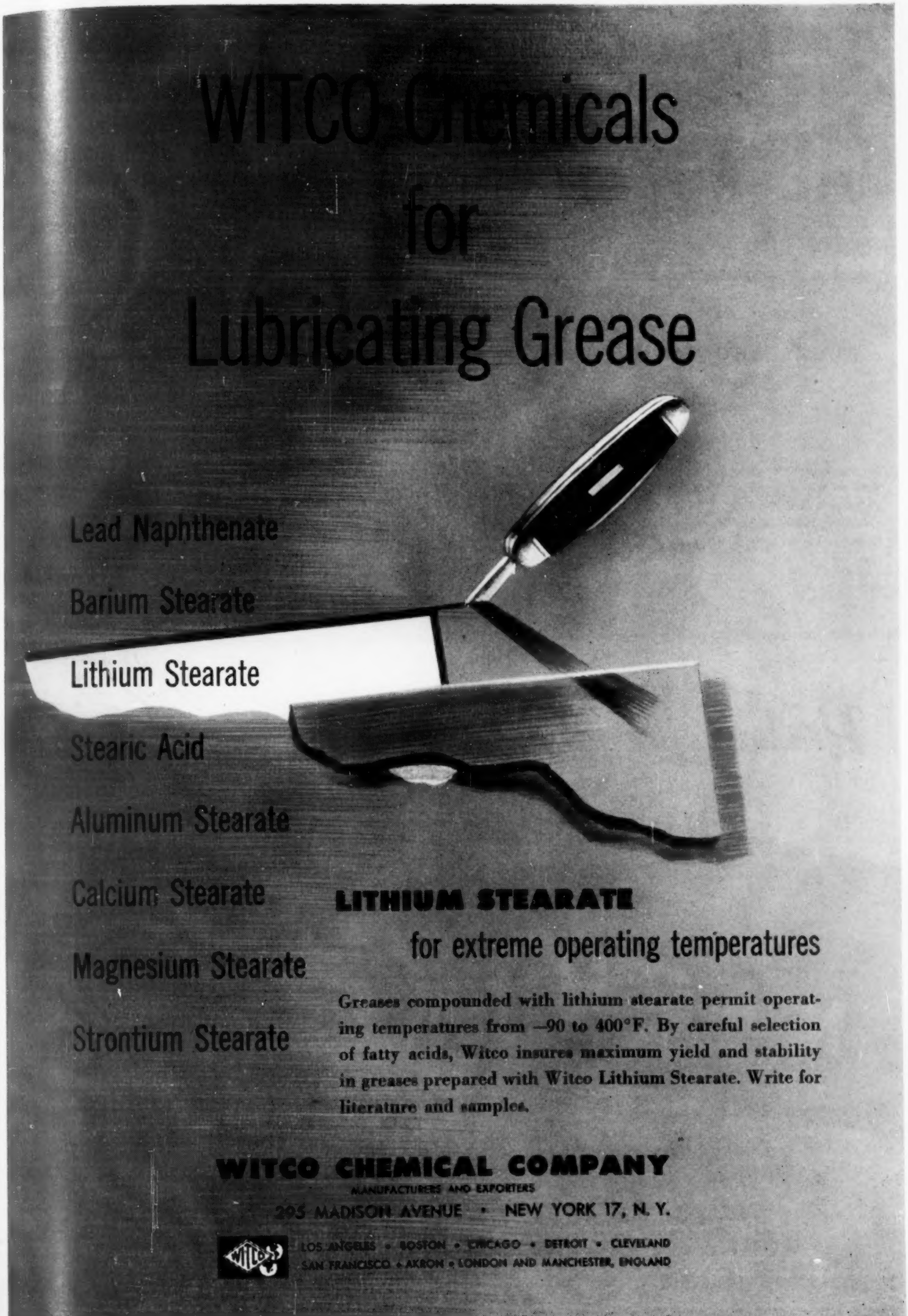

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President's page

by B. G. Symon, President N.L.G.I.

I am very pleased to see Colonel Cotulla's article, "Defense Requirements for Lubricants Relating Especially to Greases," appear in the "Spokesman". An article of this type offers one more evidence of the fact that the armed forces are continuing a liaison with industry that is vitally necessary if various industries and appropriate military units are to stay abreast of each other's needs and keep informed about new developments.

Certainly this cooperation must always be close and realistic if our national economy is ever called upon to support another mobilization program. And if our experience during the last war is any criterion, there lies between our industry and the armed forces a wide area of mutual interest, with unlimited opportunity for profitable exchange of views and information.

The need for such cooperation became apparent early in the war, and after some difficulties was met with really remarkable success. It is common knowledge that failure to meet might have spelled defeat. And now it is clear that the need has continued pressing even since the end of hostilities.

While the armed forces are now using considerably less volume of petroleum products, including all types of lubricants and greases, than they did during the war, it is interesting to note that for the fiscal year ending June 30, 1949, military requirements of petroleum products are estimated at 92,229,000 barrels—or 252,692 barrels a day. This is almost seven times as much as the military took ten years ago.

It follows, therefore, that a continuous exchange of views, whether it's through the medium of articles like Col. Cotulla's or a meeting of personnel, is necessary both to maintain a sound economy in our industry and to stay prepared. If the military and our industry work intelligently for an understanding of each other's problems, if we sit down together to thrash out what seem to be serious differences, I am sure that we'll discover a common ground even broader than the one we already know.

I also want to call to your attention two other excellent articles appearing in this issue—"Soap as a Lubricant" by C. J. Boner, and "Fluor Announces Completion of New Sinclair Barrel-House Grease Plant" by Wallace A. Craig.

Soap as a Lubricant

by C. J. BONER
Chief Research Chemist
Battenfeld Grease & Oil Corp.

Purpose of Paper

THE OBJECT of this paper is two-fold: first, to emphasize that soap is really a lubricant and not alone a carrier for oil; second, to indicate that all soaps of the same chemical composition are not equal in value as lubricants.

Dry Soap as a Lubricant

Illustrations of the use of soap alone as a lubricant are so numerous that only a few need be mentioned. Metal and wood screws, especially the latter, are often forced into place against considerable shearing forces, hence a lubricant is advantageous. Calcium and zinc stearates have been used for such purposes with good results. Most carpenters, however, use hand soap.

In expanding tubes when erecting boilers, soap pastes are used to reduce friction.

In drawing wire a pressure of 18,000 to 30,000 p.s.i. is developed within the die, hence, lubrication is required in order to reduce the resulting friction. Soap is almost universally used for this purpose, in many cases the wire passes through a bed of dry soap powder, picking up enough soap to lubricate it as it passes through the die. In addition to sodium soap, aluminum palmitate, and aluminum, calcium and zinc stearates are used. Williams (15) claims that a film of electro-deposited heavy metal soap on a wire is an effective lubricant. This is effected by using the wire as a source of the metal and a sodium stearate bath as a source of the anion. It is stated that more than 11,000,000 pounds of soap are used annually for wire drawing.

In molding plastics and rubber, a lubricant is desirable and barium, calcium, lead and zinc stearates have been found useful for the purpose. In fact any of the above and also magnesium stearate are employed to increase the "slip" of metal, wood, fiber, plastics, rubber, paper and leather. Granular materials are made more free flowing by a coating of metallic soaps which act as lubricants.

Soap Solutions as Lubricants

When drawing some of the finer sizes of wire, aqueous solutions of sodium soap provide lubrication. Likewise, in drawing copper and brass, as in the manufacture of cartridge cases, such soap solutions are largely used; and, the same lubricant was even employed in drawing some steel shell cases. How large this consumption is can be gauged by the fact that one small arms ammunition plant at one time used two carloads of soap chips per month.

In some of his early work on extreme pressure lubricants, Mougey (13) found that a solution of sodium oleate in water was more satisfactory than other lubricants tried.

For the lubrication of plastic-bonded fabric bearings Stuart (14) recommends a water solution of sodium oleate.

Previous Work

Hannegan (9) investigated the effect of metallic soaps upon the lubricating properties of mineral oil, particularly as to the effect on the coefficient of friction. Metallic soaps of cadmium, copper, lead, magnesium, nickel and zinc were prepared which had almost the theoreti-

CHARLES J. BONER is a mid-westerner by birth and education. Born in Kansas, he received his education at the University of Missouri, where he obtained a degree in Chemical Engineering.

Mr. Boner has been with the Battenfeld Grease & Oil Corporation for twenty-one years, and for the past twelve years has been responsible for the direction of their Research Program.

A member of the American Chemical Society, he is past Chairman of the Kansas City Section. He is also on the staff of Chemical Abstracts.

Author of numerous articles, Mr. Boner has a chapter in Volume VI of Alexander's Colloid Chemistry, covering "Colloidal Characteristics of Lubricating Greases".

TABLE I

Kind of Soap	Percent of Metal Actual	Percent of Metal Theoretical	Percent Soap	Coff. of Friction
None-Base oil only	....	....	0	.142
Cadmium oleate	16.64	16.655	0.1	.128
Cadmium oleate	....	....	0.5	.123
Cadmium oleate	....	....	1.0	.121
Copper oleate	10.06	10.154	0.1	.118
Copper oleate	....	....	0.5	.113
Copper oleate	....	....	1.0	.103
Lead oleate	26.92	26.919	0.024	.110
Magnesium oleate	4.14	4.144	0.1	.107
Magnesium oleate	....	....	0.5	.098
Magnesium oleate	....	....	1.0	.088
Nickel oleate	9.46	9.448	0.1	.114
Nickel oleate	....	....	0.5	.088
Nickel oleate	....	....	1.0	.082
Zinc oleate	10.40	10.412	0.01	.117
Zinc oleate	....	....	0.05	.110
Zinc oleate	....	....	0.078	.109
Oleic acid	....	....	0.1	.112
Oleic acid	....	....	0.5	.104
Oleic acid	....	....	1.0	.095

Note: Base oil was a neutral, Saybolt viscosity @ 100°F.—187.6.

cal content of metal (see Table 1) indicating that no free oleic acid was present. As is shown in the table, addition of these soaps to the base oil lowered the coefficient of friction in each instance, the value continuing to decrease for each increase in concentration of the soap. The friction tests were made on a Herschel Oiliness Machine which consists essentially of three steel balls sliding upon a flat plate. Merchant (12) built a testing apparatus consisting of two cast iron blocks on the table of a milling machine, one sliding over the other and with a spring load. Since Bowden (4) and co-workers had shown that the means by which oleic acid reduced the friction between ferrous metals was through the formation of iron oleate on the surfaces, Merchant used this additive with this reaction in mind. Tests were first made with a paraffin oil and then with the same oil with the addition of various proportions of oleic acid up to one percent. Not only was both the static and kinetic friction higher before the addition of the oleic acid, but also a condition of stick-slip occurred with oil only which was converted to smooth sliding when 0.2 mole percent of oleic acid was present.

Merchant reasoned that "The fact that the kinetic friction is also reduced by the presence of the oleate film suggests that the long aliphatic carbon chain of the latter is able to minimize the effects of surface roughness even under semi-hydrodynamic conditions. This appears to be characteristic of polar surface films."

After testing oil which contained oleic acid, the surfaces of the blocks were wiped free from all liquid, using a clean cloth. The blocks were then run in what appeared to be a dry state and the friction was unchanged, even after prolonged periods at high loads. The implication was that an adsorbed film of iron soap remained and provided effective lubrication. Following the above tests with apparently dry blocks, paraffin oil was added and tests continued with a resulting low friction value.

A recent report (3) bears out the fact that soap contributes to lubrication. It was found that in roller bearing lubrication grease allows a lower temperature rise over ambient than does oil. In the tests cited an oil of 150 seconds S. U. viscosity at 100°F. showed a rise over ambient of 92°F., while a lubricating grease containing oil of 105 seconds S. U. viscosity at 100°F. showed a temperature rise of 25°F. and a grease with an oil of 300 seconds S. U. viscosity at 100°F. showed a rise of 45°F.

Experimental Work

An Almen E. P. Testing Machine was used to determine not only the relative value of various soaps as lubricants, but also the comparison in lubricating value with other materials. Results are shown in Table II. This is a familiar E.P. testing instrument where split bearings exert pressure on a ¼-inch shaft rotating at 600 RPM. A load of 1000 pounds per square inch is applied every ten seconds until scoring of the metal occurs or until a full load is applied. Normally, the load which a lubricant will carry for ten seconds without seizure is reported as the film strength. In most of our tests, we added the load at the above rate but when a load of either 5000 or 6000 pounds was reached, the run was continued until seizure occurred.

With the exception of two soaps obtained by extraction of lubricating greases, the soaps tested were dry powders which of course did not lend themselves as readily to application as would liquid or even plastic products. In conducting a test some of the soap was placed between the bearings and the shaft when the machine was assembled. Following complete assembly, soap enough to cover the shaft was added.

To determine if other solids would perform as well as soap, tests were made with a graphite of 200 mesh containing 99% graphitic carbon and with a mica of 100 mesh. Both these gave immediate failure with a load of 1000 pounds per square inch.

The same was true of a silicon fluid with a 1000 pound square inch load and of a SAE 20 solvent neutral oil with a 5000 pound per square inch load.

All of the soaps tested were either neutral or basic, hence the lubricating value cannot be attributed to any free fatty acids present. They were commercial products, no doubt, prepared by metastasis. From Table II you can see that all of the soaps tested had some lubricating value and in most cases kept the metal free from scoring for several minutes. In contrast the mineral oils tested gave immediate seizure at loads of 4000 or 5000 pounds per square inch.

In order to determine if the soap in some of our lubricating greases was the primary lubricant, two greases, named a No. 2 NLGI grade of calcium base grease, containing an oil of 300 seconds S.U. viscosity at 100°F. and a complex barium soap grease, containing an oil of 500 seconds S.U. viscosity at 100°F., were selected. The oils used in compounding these greases were tested as were the finished greases. Then repeated extraction of each grease with acetone was carried out to remove the mineral oil, free fat and fatty acids. The resulting soaps were tested and since no seizure occurred in thirty minutes with a load of 5000 pounds per square inch, the load was

increased to 10,000 pounds per square inch using new shafts and bearings. Still no failure occurred. This in contrast with immediate seizure at a load of 4000 pounds per square inch with either oil and a seizure in a few minutes with either grease at a load of 5000 pounds per square inch.

Since the fats used in the two test lubricating greases had titers of about 42, the recovered soaps were gummy products rather than dry powders. This physical state no doubt gave a better distribution of the lubricant than in the case of the dry soaps.

From the above experiments, it seems reasonable to conclude that the soap in these particular lubricating greases is a primary lubricant, rather than merely a carrier for the mineral oil. Further, any soap tested provided a better protection against seizure than did any mineral oil tested.

Nature of Soap Film Contributing to Lubrication

Langmuir (10), working with monomolecular films of metallic soaps, found that the carboxyl groups of the soap attached themselves to the polar metal and the long chains projected at an angle. If two metal surfaces, which are adjacent, are coated with such oriented films, it is found that effective lubrication is obtained. What is visualized is that we have a structure much like bristles on a brush, with the ends free to glide over one another. Germer and Starks (6) found that mild rubbing would remove all but one molecular layer of barium stearate from a chromium surface and that further rubbing did not remove this layer. This soap molecule, perpendicular to the surface, was shown in an X-ray projection of the above surface.

The surface which can be covered by such a film is large in comparison with the amount of soap involved. It is stated that metal stearates are now made which give a coverage of 22,000 to 25,000 square cm. per gram of soap (1).

Hannegan (9) stated "from the shape of the curves obtained by plotting the coefficient of friction against the concentration of soap, one would be inclined to believe that adsorption of the soap on the lubricated surfaces was taking place as the curves are similar in form to the adsorbed isotherm."

Gallay and Puddington (7) were able to demonstrate the orientation of soap toward a polar surface by heating calcium stearate to 150°C in either glass or platinum and then allowing the mass to cool. By this means, they were able to obtain polar surfaces on the portion of the soap adjacent to the container while an interior surface, planed off smooth, was non-polar. The same treatment in a vessel of fused quartz did not show this orientation. These workers state that "the formation of a surface of a polar nature against glass or platinum must involve the exposure of calcium carboxylic groupings on that surface."

In order to prevent metal-to-metal contact of surfaces to be lubricated, the lubricating film must be so firmly bound to the metal that it will resist pressure and shearing forces which tend to rupture the film. Since most mineral oils do not have polar characteristics, they do not attach themselves to the metal in the same way that soaps do. In the case of the soaps the polar end is attached firmly to the metal surface and the long chains of the non-polar end project into the oil layer. It is readily seen that since this gives an orderly arrangement, less work will be required to move one film over the other than if the arrangement were random. The advantage of soap over other polar agents was shown by Germer and Starks (6) who found that hydrocarbon chains of barium stearate on metal were more precisely oriented than those of stearic acid.

How firmly soaps adhere to metal is shown by an observation of Hannegan (9) who found that if oil containing free oleic acid was permitted to stand on polished steel plates, the surface darkened, presumedly due to the formation of iron soap, and that the darkened area could only be removed by abrasives. Others have found the same conditions as shown in a statement in Lubrication (2): "When one end of the lubricant molecule is highly reactive, it has the property of forming a powerful bond with a steel surface. Then, it is called a polar molecule. It is 'adsorbed' to the surface so powerfully that the last traces can only be removed by grinding. A straight mineral oil has no such effect."

All this then comes back to the adsorption hypothesis of lubrication

(Continued to Page 11)

Soap As a Lubricant

(Continued from Page 9)

in which it is suggested that the bearing metals have a stronger attraction for certain types of molecules than for others and that molecules of these types will separate out of the oil to form a tenacious, concentrated film which will cling to the surface long after a hydrodynamic film has been squeezed out.

Physical State of the Soap

Conceding that it has been shown that soaps have advantages as lubricants, it seems quite evident that the soap will have a better chance to act as a lubricant if it is in the proper physical state. Many of the metallic soaps are solids with melting points ranging up to 500°F. If such soaps were used as is, no doubt the excess soap which could not become attached to the metal surface would pile up and be an obstruction to movement of the machine parts. Therefore, if such soaps can be used in a plastic or semi-fluid mixture, they should be more satisfactory. This, then, points to a product of the nature of a lubricating grease.

Our conception is that the mineral oil portion of a lubricating grease is simply a carrier for a dispersion of the soap which is the primary lubricant. We must have true dispersion and not simply a mechanical mixture. In the latter case, we might have not only the piling up of solids mentioned before, but also large aggregates of the soap molecules which would not have the chance to orient themselves as will smaller micelles or even molecules.

This brings us to a weakness of not only the generally prevelent conception of what a lubricating grease should be but also the deficiency of present specifications. Some feel that if specifications are set up with a certain percentage of a definite metal soap, etc., they will obtain a uniform product. Perhaps such ideas originated because a lubricating grease supplied by A, which fell in the soap content specified, performed satisfactorily. However, suppliers B and C complied with the specifications, yet their products failed badly in service. Until due recognition is given to the fact that processing and consequent physical state of the soap is more important than other specifications in many lubricating greases, the user will not always obtain the most satisfactory service from such products.

Since most readers of the Spokesman are in general conversant with the manufacture of lubricating greases, the factors which may influence the physical state of the soaps will not be discussed. However, it is of interest that five or more phases are possible with water and any pure sodium or potassium soap. That point is illustrated with some jars of potassium oleate in water prepared by Dr. Vold. The solid phase, representing "middle soap", contains only 25% of potassium oleate, while the liquid product, representing "neat soap", contains 65% of potassium oleate.

McBain and Mysels (11) stressed the variation in the physical state of aluminum dilaruate even when the chemical composition was the same. In one physical state this soap was completely soluble in certain hydrocarbons while in another physical state it was almost insoluble. The same situation was encountered with aluminum soaps used for gelling gasoline during the late war. The soap produced by one supplier formed a gel readily in a certain gasoline while that supplied by two other suppliers would only form such a gel with difficulty. Analysis indicated that the three soaps were the same chemically.

Calcium stearate was heated in mineral oil by Galley and Puddington (8) who found that "on cooling the highly dispersed sol, depending upon the unsaturation of the soap, the nature of the oil, or the presence of various solvent factors, gave a wide range of physical properties with the same soap concentration, e.g., (a) a smooth lubricating grease of short texture, (b) a thickened oil of low consistency, (c) a thickened oil of grainy texture, (d) pieces of coagel of free oil, changing on standing to a complete separation of hardened soap and free oil."

As a further illustration of this point, a mixture of aluminum stearate and mineral oil was heated to 300°F. A portion of this was poured on a metal table top in a thickness not exceeding ⅛ inch. This represents rapid chilling. Another portion was placed in a beaker which was wrapped with cloth so that the insulation provided slow cooling. Samples of these two products, of the same chemical composition, clearly indicate there is some difference in the physical state of the soap. One product would be acceptable to the trade the other could not be marketed.

TABLE II

Results of Tests on Almen E. P. Testing Machine

Lubricant	ASTM Acidity or Alkalinity	Loads Lbs. Per Sq. In.	Torque	Period after Loading before Failure
Dry shaft		1000	----	10 sec.
99% pure graphite		....	----	
200 mesh		1000	----	Immediate
Ground mica 100 mesh		1000	----	Immediate
Silicon liquid		....	----	
500 cstks @ 25°C		1000	----	Immediate
SAE 20 High VI oil		5000	----	Immediate
SAE 30 Smackover oil		5000	16	6 min. 15 sec.
Barium Stearate A	neutral	6000	6	12 min.
Barium Stearate B	neutral	5000	5	6 min. 20 sec.
Calcium Stearate	0.01% alkaline	5000	5	8 min.
Lead Stearate	neutral	5000	5	3 min. 50 sec.
Lead Stearate basic		5000	5	37 sec.
Lithium Stearate	neutral	5000	6	1 min. 40 sec.
Lithium Stearate	0.01% alkaline	5000	7	12 min.
Sodium Stearate	neutral	5000	5	9 min.
Strontium Stearate	neutral	5000	6	35 min. no failure
Ca Cup 300 oil #2 NLGI	alkaline	5000	11	4 min. 15 sec.
Oil from above cup		4000	----	Immediate
Soap from above cup	alkaline	5000	2	30 min. no failure
Soap from above cup	alkaline	10000	----	No failure
Complex Barium Grease	alkaline	5000	----	25 sec.
Oil from above grease		4000	----	Immediate
Soap from above grease	alkaline	5000	2	30 min. no failure
Soap from above grease	alkaline	10000	----	No failure

Conclusion

Both theory and experimental evidence point to the fact that soap has lubricating value and consequently this component of Lubricating Greases is a lubricant and not alone a thickener.

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The first oil company drive-in service station was opened in 1903. Today there are 250,000 and 95 per cent of them are independently owned, or operated. There are more service stations than post offices.

Defense Requirements FOR LUBRICANTS

. . . RELATING ESPECIALLY TO GREASES

by COLONEL L. E. COTULLA
Executive Officer
Armed Services
Petroleum Purchasing Agency

The Armed Services Petroleum Purchasing Agency sincerely welcomes this opportunity to discuss with you the requirements of the military in lubricants and particularly in greases.

The military establishment has many problems confronting it with regard to petroleum products. The determination of requirements, the purchase of products from industry and their distribution all are essential steps in the supply program and all present difficulties at times. In addition, there are technical problems involved in the determination of the proper type of lubricant to service newly designed equipment or in the improvement of the performance of the lubricant currently in use.

Many of our problems have been solved through the cooperation of industry. Continued research and development and cooperation of industry will do much to bring about a solution to our present problems and will minimize those of the future.

Armed Services Pool Petroleum Purchasing

Before discussing the requirements of the military, it is believed desirable to take a few moments to present as a background, the framework of the organization which is now responsible for presenting those needs to industry.

During World War II, the Army and Navy were each responsible for the purchase of petroleum products to meet their respective needs. The fact that there was an adequate supply of lubricants to meet every vital need is both a tribute to industry and an indication that the military supply system did function.

The establishment of the Air Force as a separate Department together with a much closer balance between supply and demand for petroleum products led, early in this year, to the formation of the Armed Services Petroleum Purchasing Agency. The Agency has been in existence since May 1 and is responsible for the purchase of all petroleum products for the National Military Establishment.

The actual determination of requirements both as to volume and as to specification remains with the three Departments. The Agency consolidates the requirements and contracts with industry for the products to meet their needs. The advantages of a single purchasing agency are numerous—not the least of which is the fact that industry now has only the one agency to contact relative to the Armed Services' needs.

The Petroleum Purchasing Agency is directly responsible to the Departments of Army, Navy and Air through a directorate of three senior officers, each representing one of the Departments. Rear Admiral E. D. Foster, Chief of the Bureau of Supplies and Accounts, is Chairman of the Directorate: Major General T. B. Larkin, the Quartermaster General, is the Army member and Major General L. P. Whitten, Director of Supply and Maintenance, is the Air Force member.

The data on the requirements in lube oils and greases presented here were obtained for the most part from the records of the Purchasing Agency. They represent the combined needs of the Department of National Defense. They do not include any requirements of other governmental agencies or for ECA al-

COLONEL L. E. COTULLA was born in Texas on January 16, 1904. He graduated from the Colorado School of Mines in 1925 with a degree in Geological Engineering. After Colonel Cotulla's graduation he was engaged as a geologist by several well-known petroleum companies until 1933 when he was appointed a Company Commander with the Civilian Conservation Corps. Colonel Cotulla (then Captain, Engineer-Reserve) served with the Civilian Conservation Corps until 1936; then followed several years of activity as a Petroleum Engineer at various oil fields engaged in salt water disposal, bottom hole pressure tests, etc.

Colonel Cotulla's military experience began in 1925 when he was appointed Second Lieutenant in the Engineer Corps Reserve. By December of 1940 he had attained the rank of Major and was called into active service in that grade and assigned to duty with the War Department General Staff. Within two years Major Cotulla attained the rank of Colonel and held key assignments until his release from active duty in February of 1946.

In July of 1946 this officer was appointed in the Regular Army in the permanent grade of Major and recalled to active service as the Area Petroleum Officer, Caribbean Defense Command, in the temporary grade of Colonel.

Colonel Cotulla was selected for attendance at the Army Industrial College in 1947 and upon graduation was assigned to duty with the Army-Navy Petroleum Board. The Charter of the Armed Services Petroleum Purchasing Agency provides that an Executive Officer shall be selected from the three Services (Army-Navy-Air Force) in rotation. Colonel Cotulla has been selected by the Department of the Army for this assignment and will serve for a period of two years.

In 1945 Colonel Cotulla was awarded the Legion of Merit for outstanding services at the New York Port of Embarkation. Charged with the task of facilitating the movement of equipment to troops in theaters of operations, he put into effect a priorities system at the Port and its nine out-ports that did much to solve the supply problems incident to mounting and maintaining offensive in western France and Germany.

though the civil requirements in occupied areas are combined with those of the military.

During the past fiscal year, ending June 30, the military procured about 50 million gallons of lube oils and about 10 million pounds of greases. The estimated requirements for the current fiscal year indicate a need for about 65 million gallons of lube oils and some 11 million pounds of grease.

Navy Grease Consumption Cut

It is emphasized that the above data are for procurement planning purposes and do not necessarily represent actual operating needs. For example, the Navy Department has required very little in the way of additional purchases of greases since the close of the war. The current consumption of greases by the Navy is less than 15% of the peak yearly wartime requirement which was between 15 and 16 million pounds. Nominal reserve stocks for the emergency period represent several years' supply at present rates. Current procurement of greases is largely to meet Army and Air Force requirements which represent about the same percentage of their peak wartime needs of 60 million pounds of grease per year as do the Navy consumption figures.

90% Military Consumption Is General Purpose Grease

An analysis of the estimated 65 million gallon requirement of lube oils for this year indicates that about 40% will be aircraft engine oils, another 40% motor oils and the remainder made up of special lubricants such as machine oil, cylinder oil, red engine oil and the like. Nonlubricating oils such as cutting oils, preservative oils and hydraulic oils add almost a million gallons to the above requirements.

General purpose greases for automotive equipment make up the bulk of the grease requirements. It is expected that about 90% of the military procurement in greases for the fiscal year will be of these types. The remainder will be made up largely of special products such as chain and wire rope lubricants, plus valve grease, etc.

No Change Expected In Military Grease Requirements

In a future emergency—certainly in any one occurring in the next few years—the demands of the military may be expected to be similar in volume to those of World War II. Much of course depends upon the size of the forces and the areas in which they are employed. If the thesis is accepted that, regardless of new weapons, it will still require armed manpower to occupy and hold enemy territory, the military will continue to be dependent largely upon motor transport for support. This will be true in this hemisphere or in any other area and whether the forces are air force, ground crews or infantry.

It is not meant to imply that no new products will be needed. As new equipment is adopted, new lubrication problems will arise and new greases and lubricants will be required. For sometime, however, requirements of any volume may be expected to remain centered, for the most part, around those types of lubricants now in use. This applies equally to all three Departments. Air Force requirements, except those relating directly to aircraft, are now included with those of the Army. Fortunately, the newest types of aircraft, while presenting severe lubricating conditions, do not impose a heavy volume demand.

Research For More Versatile Grease

Extensive research is being carried out by the Armed Services on lubricants and substantial progress has been made in the development of low temperature lubricants. The Naval Research Laboratory has found that excellent low temperature greases can be prepared from diesters, silicones, and silicone-diester mixtures thickened with lithium stearate. These greases not only possess satisfactory characteristics, at temperature as low as 100°F. but exhibit low evaporation rates at moderately elevated temperatures. With some improvement in wear characteristics and an extension of the high temperature range a truly universal grease for aircraft may be developed.

In the meantime, the Air Force is of the opinion that for the immediate future, grease lubrication of aircraft will be limited to four greases that overlap sufficiently to take care of all present requirements as well as almost any eventuality in future designs.

The Naval Research Laboratory has also developed an oil and a grease for fire control instruments from diesters. With improved stability, these lubricants will permit satisfactory performance over a wide temperature range.

The Armed Services are making every effort to increase the application and temperature range over which lubricants can operate successfully. This will simplify both the manufacturing problems for industry and the supply problems for the military.

An example of the work being carried out by the military is the road test of vehicle lubricants now in progress. This test is being conducted by the Army Ordnance Department in connection with its search for a grease that will perform satisfactorily over a temperature range of from plus 125 degrees to minus 65 degrees as well as stand up under storage conditions ranging from a plus 165 degrees to a minus 80 degrees. All temperatures are Fahrenheit. Twelve greases of various types, both synthetic and natural, were tested in the laboratory and the six most promising selected for road testing. A convoy of 12, 2½ ton trucks, using these lubricants, has departed from the East Coast on a 20,000 mile trip which will carry it to the California desert, then to Alaska for the winter months and finally back to Aberdeen Proving Ground.

One interesting feature which developed from cold tests of automotive lubricants was that only a small amount of standard warm weather grease left in the mechanism of the vehicle, when changing over to low temperature greases, was sufficient to lock the mechanism when temperatures were dropped to minus 50 degrees. To convert a vehicle to cold climate operation, it is necessary that the transmission differential, wheel bearings and other lubrication points be completely disassembled, washed out thoroughly and reassembled with cold weather grease. In an emergency involving demands for vehicles in the far North, the loss of time and the manpower to effect the changeover could be most serious.

If the military is successful in the development of satisfactory lubricants for the wide temperature range that will be encountered by the convoy, it will mark a long step forward in automotive lubrication. Such lubricants, when and if commercialized, may greatly benefit motorists, particularly in the Northern states.

Military and Industry Must Work Together

The Armed Services will, of course, continue their experimental and development work. It is mandatory that as the needs of the services for lubricants develop, complete information concerning them be given industry so that satisfactory products may be forthcoming.

It is only through an exchange of information between the military and industry that assurance may be obtained of an adequate supply of lubricants in an emergency. The grease manufacturing capacity is apparently adequate although some of the material required for special products for military use may be in short supply.

The Armed Services will continue to cooperate with industry to the maximum. To this end, all military information on lubricants and greases will be made available to you to the extent that security permits.

The Armed Services appreciate your interest, understanding and support and are confident that whatever the problems of the future may be, with your assistance they can be speedily resolved.

You get a "BONUS" in both QUALITY AND PACKAGING WITH AERO* BRAND STEARATES

When you specify Aero Brand Stearates for your lube requirements, you get a two-fold bonus:

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INDUSTRIAL CHEMICALS DIVISION

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

CHAIRMAN T. G. ROEHNER, DIRECTOR OF THE TECHNICAL SERVICE DEPARTMENT, SOCONY-VACUUM LABORATORIES.

Fraser, Kaufman, Zweifel, Hemmingway Named To Head Newly-Formed Subcommittees

Steady progress is being made in organizing the Subcommittees which were discussed at the Annual Meeting of the Technical Committee in Chicago. Mr. H. M. Fraser, of International Lubricant Corporation, has agreed to serve as Chairman of the Subcommittee for the Procurement of Technical Papers for publication in The Institute Spokesman. The membership of this group will be quite large, so that it will, in effect, cover the country and all of the interests represented on the Committee. It is hoped that their activities will uncover papers which will contribute technical data of immediate value to the industry. It is intended that these papers will supplement, in an important way, those given at the NLGI Annual Conventions.

Mr. Gus Kaufman, of The Texas Company, will serve for one year as Chairman of the Editorial Subcommittee. All technical papers before publication in The Institute Spokesman will be checked by this group. Messrs. E. W. Adams and C. W. Georgi have been lined up for this activity and Mr. Harry Bennetts will function as Secretary. The final membership of this Subcommittee and others will be given in this Column as soon as completed.

Organization of the Subcommittee on Planning is also under way, under the Chairmanship of Mr. H. C. Zweifel, of Union Oil Company. This group will study the advisability of setting up projects on so-called engineering problems and will prepare a report to be presented at the New Orleans Meeting of the Technical Committee. Their report is expected to contain recommendations regarding various projects for obtaining fundamental information useful in answering the many questions involving manufacturing equipment, such as mixing equipment, pumps, filters, etc.

Mr. Hugh Hemmingway, of Pure Oil Company, is organizing the Subcommittee on NLGI Classification of Greases. His group will study proposals to increase the value of that classification by keeping it in step with progress within the industry.

A major reason for giving the names of the Chairmen of the above Subcommittees is to make it possible for any member to easily volunteer for participation in any of the activities in which he may be particularly interested. *You are urged to write direct to the Chairman of the particular Subcommittee in which you are interested, or to the Chairman or Vice-Chairmen of the Technical Committee, indicating your interest, so steps may be taken while organization is still in progress.*

The Panel on Delivery Characteristics of Dispensing Equipment for Lubricating Greases is studying the results obtained from the first series of exploratory tests and a meeting will be called in the near future to decide on the next steps. Thereafter, detailed information regarding the first series of tests will be released for publication in The Institute Spokesman.

Lithium Grease Royalty Rate Reduction Announced by Foote

Since 1942 when the Foote Mineral Company became the sole licensor of the basic lithium grease patents, there have been three reductions in the royalty rates and despite an increase of 35% in all chemical prices during this period, lithium hydroxide prices have been reduced 17%.

In the past year Lithium grease use has expanded from the "Specialty" field to become firmly established in the automotive and industrial field. The new schedule, which became effective January 1, 1949, was specifically designed to cope with the economic problems presented by these large volume fields. It is believed that the reduced rate will enable more manufacturers to offer lithium greases in these fields for which their unique properties so well fit them.

Mr. H. L. Cato Dies

With a useful life of more than three score and ten years behind him, the head of the Cato Oil and Grease Company, Oklahoma City, Oklahoma, died on December 31st, 1948. He was laid to rest on January 3rd, 1949.

He organized his Company more than twenty-six years ago with Mr. James R. Corbett and Mr. Claude C. Huffman as associates. They have continued together very successfully during these years.

Mr. Cato was born in Aquilla, Texas, and began his work in the oil industry in the sales department of the Waters-Pierce Oil Company in 1903, and had been associated with the oil industry since that time. He was a man of high regard and was loved by all who knew him.

Armour Publishes Booklet On Fatty Acids

Although the commercial importance of the fatty acids and their derivatives has grown steadily and rapidly during the recent years, technical information on them has had to be culled from incomplete and diverse chemical references. Realizing this Armour and Company has produced a 12-page booklet on fatty acids entitled THE CHEMISTRY OF FATTY ACIDS.

The number of known acids and their derivatives (ketones, aldehydes, esters, alcohols, amines, amides, nitriles, metallic salts, etc.) run into thousands of compounds. In this booklet a number of these compounds are described including their sources and applications.

The book was written and compiled by top men who have spent many years in research and practical field work on fats, oils and fatty acids.

The information contained in THE CHEMISTRY OF FATTY ACIDS is of special interest to the technical and production staffs of present and prospective users.

"Spokesman" readers may obtain this free booklet by writing to Armour and Company, 1355 West 31st Street, Chicago, Illinois.

ABOUT THE COVER PICTURE

Vari-Temp Ductility Apparatus

Precision's Vari-Temp Ductility Apparatus was developed for testing bituminous roofing and paving materials in accordance with A.S.T.M., D113. Ease of operation is featured in having one temperature control knob, one lever for pull-speed selection, and one lever for start-stop of carriage.

The machine incorporates automatic control of bath temperatures from 32°F. to 100°F. and holds a set temperature within plus/minus 5°F. Two heating elements, totalling 600 watts, and the cooling coils are located in the outer shell of a double-walled bath where agitation from the circulation pump cannot disturb bath water around samples.

There are three pulling speeds, ¼, 1 and 5 cm per minute. Three samples can be tested simultaneously, and a large storage compartment has space for conditioning 8 samples. The samples are pulled over a full length "milk" glass panel with no carriage sway or chatter. Carriage is automatically stopped by a micro-switch at end of 150 cm. travel.

The motors for refrigeration and circulation are resilient-mounted, the rigid frame is made of steel angles and channels, insulation of Zerolite and glass wool surrounds the bath tank. The cabinet, 36" high—110" long—27" wide, has rounded corners and panels of sheet steel finished in Hammerloid enamel. Plate glass covers give undistorted view while testing and keep the bath clean when the machine is not in use.

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HARRY F. BENNETTS .... *Editor*

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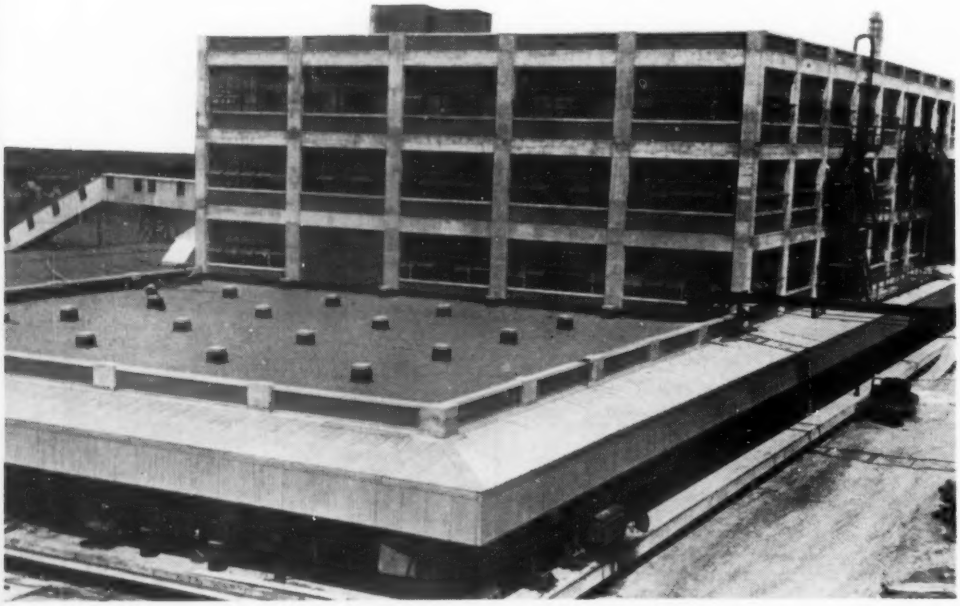
Fluor ANNOUNCES COMPLETION OF

New Sinclair Barrel-House Grease Plant



by WALLACE A. CRAIG

Senior Engineer

The Fluor Corp., Ltd.

The Fluor Corporation, Ltd. of Los Angeles, has recently completed a new plant for the Sinclair Refining Company in their Houston Refinery for filling lubricating oil in barrels and cans and for manufacturing and packaging grease. These new facilities will supply oil and grease to the Southern States and a large portion of the Mid-Continent area.

The plant consists of a four-story building with basement, supplemented by a one-story building to house barrel cleaning operations, the total floor space amounting to about 200,000 square feet. The main building is divided so as to segregate the lubricating oil operations from the grease manufacture. This building is fire-proofed structural steel above the first floor and reinforced concrete below that point. The building site is within a few hundred feet of the Houston Ship Channel, and the water table is relatively near the surface of the ground. The basement, therefore, was limited in depth by this fact, while the maximum height of the first-floor was limited by the elevation of the railroad spurs adjacent the building. Reinforced concrete construction was selected for the lower portion of the building because it was possible to design shallow beams to offset the impaired head-room. The building walls are brick with a maximum amount of windows to provide the greatest amount of light and ventilation. The Drum Reconditioning Building is a steel frame building covered with Robertson Protected Metal. Much of it is open at the sides to provide as much ventilation as possible. Two compressors are located in this building, one furnishing air at 100 psi for line blowing, and other services, and one furnishing air at 35 psi primarily for the Portco Drum Washers.

Lubricating oil is obtained from another section of the refinery and is handled by 17 Yale & Towne pumps located in the east end of the basement. From here, the oil can be pumped to filling tanks, blending kettles, or the Grease Department, as may be required. These "Tri-rotor" pumps are gear type. Sudden blocking of the discharge line shifts the rotor into a neutral position, where it will idle until the discharge is opened. This is a desirable feature for pumping operations when the flow is interrupted frequently. The filling tanks are located on the third floor of the building and are provided with pipe lines which lead to the can fillers on the second floor and the barrel fillers on the first floor. Each line has a swing pipe within the tank which can be raised above the oil in case of emergency. The filling tanks on the third floor have been supplemented by a group of tanks located in a "hot room" located north of the barrel filling room. Cylinder stocks and other viscous oils will be stored here and maintained at an elevated temperature to facilitate handling. If a blend of oil is desired, it is prepared in one of five blending kettles of approximately 100 barrels capacity or a ten-barrel kettle. The contents of each large kettle is heated by circulating the oil through its heat exchanger by means of a centrifugal pump located directly beneath the kettle. Cooling is effected in the same manner. These kettles are provided with Lightnin' mixers to obtain thorough blending. Additional blending facilities consist of a Cornell Homogenizer having a rated capacity of 90 gallons per minute, which is equipped with a heater upstream and a cooler downstream.

Barrel filling starts with the renovation of dirty barrels in the Drum Reconditioning Building. After preliminary inspection to remove damaged packages, the barrels are conveyed to two six-unit Portco drum cleaners. Spray painting follows the cleaning, after which the barrels pass through an infra-red dryer. The painted barrels are then conveyed to the basement of the main building to be stencilled. New packages by-pass

the Drum Reconditioning Building and are stored in the basement until needed. A reciprocating hoist with an automatic feed delivers the barrels to the first floor where they are distributed on conveyors to the proper fillers. Twelve meter type fillers have been installed and are fed by Yale & Towne pumps. To reduce contamination to a minimum, each pump is provided with an oil-resistant rubber suction hose with a quick coupling, which is connected to the desired oil line. When the grade of oil is changed, the hose is disconnected, the pump reversed to clean the line, the line finally blown with air, and then connected to the new grade of oil. The filled barrels are conveyed from the fillers to a down-ender, and inspected for leaks, after which they are up-ended and conveyed over a check scales and then segregated with respect to their destination on a group of storage conveyors. When a complete order has been accumulated, the barrels on the storage conveyor are released and conveyed to the desired loading point. Loading conveyors extend the full length of the loading docks on both sides of the building and can be handled by portable conveyor when loading trucks on the west end of the building. Means have also been provided to convey barrels to a storage warehouse immediately north of the Barrel House or to the ship loading dock a short distance beyond this warehouse. The barrels are lowered into the basement, where they are down-ended and fed on a chair conveyor which carries them lengthwise. They can be removed by means of a diverter in the warehouse or allowed to continue to the dock, passing enroute under a railroad spur and a road.

Can filling starts at the point where the incoming empty cans are unloaded from freight cars. A belt conveyor system carries them to the fourth floor and distributes them in this storage area. One-quart and five-quart oil cans in their cases are delivered to unscramblers, where the cans are fed to conveyors which take them to the fillers on the second floor, while the empty cartons go down a spiral chute to the can packers. Two one-quart filling machines, complete with cappers, packers, and sealing machines are located on the second floor. One machine has a capacity of 300 cans per minute and the other about 260 cans per minute. The third line performs similar operations in filling five-quart cans. Two-gallon and five-gallon cans are handled on a separate conveyor from the fourth floor, which also handles grease cans. A six-unit Crandall machine is used to fill these packages. The packaged oil is conveyed to the package warehouse which is the west section of the first floor, or to the warehouse north of the main building or to the dock by means of an overhead conveyor system.

The grease plant consists of ten grease kettles of about 1700 gallons capacity, one experimental kettle of 120 gallons capacity, and two pressure soap kettles of 300 gallons capacity. These were fabricated by Sthruthers-Wells to withstand steam jacket pressures of 150 psi, and are provided with two-way agitation and are powered with two-speed motors.

Each of the pressure soap kettles serves four finishing kettles, discharging its contents by the internal pressure which is developed. All of the kettles are set with the tops only slightly above the floor in order to minimize the effort required to charge materials manually. Oil is introduced through meters equipped with pre-determining shut-offs. Feed tanks for fats and oils are located above the kettles on the fourth floor, while compounding ingredients are stored on the third floor and conveyed in weigh tanks which are suspended from crane scales operating on an overhead tramrail system.

Materials such as aluminum stearate, hydrated lime, or other dry ingredients are picked up in the storeroom with a chain block mounted on a trolley and deposited on a working platform from which the weigh tanks can be charged. One weigh tank is provided with an electric mixer so that slurrys of raw materials can be prepared prior to charging the grease kettles. Another is reserved for caustic soda solution, which is obtained from a small storage tank located on the floor above. Still another is reserved for tallow or other fats, and is loaded at a special station beneath the storage tanks on the floor above.

Individual gear pumps are hung from the bottoms of the kettles, and discharge grease to a can filling machine or to barrel filling, as desired. Due to the short coupling between the kettle draw-off and the pump suction, care had to be exercised to provide enough flexibility for expansion and contraction as the line heated and cooled. A bellows type expansion sleeve was installed which is expected to care for this condition. A coarse screen is located in the suction line to protect the pumps from the entrance of large pieces of foreign matter and an electric driven Cuno filter is installed down-stream from each pump to remove soap lumps or other finely divided undesirable material. The discharge lines are wound with electric heating coils which are provided with automatic temperature controls.

Two storage tanks for grease have been installed. A milling machine draws the contents from these tanks and works the product before packaging.

Empty cans are conveyed from the fourth floor and delivered to an Eveready Can Filling Machine. The filled cans are covered and cased, the cases glued and sealed automatically and conveyed to the warehouse or shipping docks.

Railroad grease is filled by means of separate lines which take it to the basement. Here, cartons are filled and allowed to cool in racks before finally sealing and storing.

Ample space has been reserved for increased output and for the installation of new process equipment when the occasion arises. Office space is located on the first and third floors.

(Continued to Page 24)

The Author

MR. CRAIG has spent most of the twenty-six years of his professional life since receiving his Chemical Engineer's Degree from Stanford University in the oil industry in California. He spent eight years with the Union Oil Company of California, during the last five years of which he was in charge of lube oil blending, compounding and filling and the manufacture of their greases. Following this, he spent eleven years in the employ of Richfield Oil Corporation, in charge of experimental work of their refinery and later as Assistant Chief Chemist. During the latter part of the War, he was a fuels and lubricants specialist in the Engineering Department of Lockheed Aircraft Corporation. He joined the Engineering staff of the Fluor Corporation, Ltd., of Los Angeles in 1945 and has supervised several projects similar in nature to the one described in this article. The Sinclair project was one of these.

New Sinclair Barrel-House

(Continued from Page 23)

The ground floor or general office has been protected against outside noise by means of an acoustical ceiling and double glazing between the office and the barrel filling room. Air conditioning was also installed.

Sinclair Refining Company prepared the preliminary design which was supervised by Mr. W. J. Mulloy of their Engineering Department. Final design and the construction of the project was done by the Fluor Corporation, Ltd.

Sales of Lubricating Oils and Greases, 1947

. . . BY STATES AND TYPES

On pages 28 and 29 you will find a splendid example of joint industry-Government endeavor. Although the N.L.G.I. is not concerned in the sales of lubricating oils, they were included with the grease statistics as a matter of interest and comparison.

This report was initiated and financed by the American Petroleum Institute and presents the results of the first national survey of sales of lubricating oils and greases by States and by types. The data were collected and compiled by the Office of Domestic Commerce at the request of the Institute.

Total domestic and export sales reported in the survey were 50,320,911 barrels or an estimated 95 percent of all sales. The remaining 5 percent is accounted for by a few scattered small firms and one of the larger companies (located on the West Coast) which failed to submit their sales data.

Although no previous sales data are available for purposes of comparison, the Bureau of Mines 1947 production, stocks, domestic demand, and export figures provide a bench mark for verifying the data collected in the present survey. In making this check it must be noted that the Bureau of Mines figures are at the production level and do not include additives. There are no official production figures on additives but an industry estimate placed output between 1,400 and 1,500 B/D as of September, 1948.[1] It is also estimated that from 10 to 15 percent of greases are composed of material other than petroleum.

The Bureau of Mines reported production of lubricating oil base stocks in 1947 at 51,765,000 barrels, with an increase in stocks of 1,060,000 barrels. Hence about 50,705,000 barrels moved into marketing channels during the year. This is in close accord with the sales data collected on a State and product basis by the Office of Domestic Commerce. A comparison excludes consideration of the stock position at the marketing level on which data never have been collected, but which would be necessary for a more precise check.

The domestic sales of lubricating oils and greases reported at 37,347,620 barrels in the survey compare favorably with the Bureau of Mines indicated 1947 domestic demand of 36,513,000 barrels. The various adjustments noted in comparing total sales account for a considerable part of this difference. A careful State-by-State analysis of the reported figures and of other related data indicates that some sales of automotive oils reported as domestic later moved into export, particularly in the States of New Jersey, Louisiana and Texas.

Reported export sales of lubricating oils and greases in 1947 aggregate 12,973,291 barrels. This figure includes shipments to United States territories. It is considerably lower than a comparable figure of 14,819,-

000 barrels arrived at by the A.P.I. statistical staff using 'official Census export data.' The latter figure includes the Bureau of the Census exports of lubricating oils and greases in Group 5 and some other white oil classified by that agency in Group 8 plus shipments to territories. However, the difference between the two figures is narrowed greatly when allowance is made for nonreporting firms and exports of automotive oils believed to have been reported as domestic sales.

Automotive oils comprised 54 percent of the sales of all oils sold in the United States compared with 31 percent for industrial lubricating oils, 14 percent for other industrial oils, and 1 percent for aviation oils. An explanation of the kinds of oils included in each classification appears at the end of the text.

The five States, Texas, California, New York, Pennsylvania and Ohio, each consumed between 1 and 1½ million barrels of automotive oils and together accounted for 32.8 percent of the total for the United States. These same States have about 34 percent of the country's registrations of consuming vehicles. New Jersey, Texas, and Louisiana appear to be somewhat high in consumption in relation to their vehicle registration. These States are primary points of exports and it is believed that some sales may have been inadvertantly reported as domestic which later were exported. Certain Western States appear to be somewhat low in relation to their vehicle registration which might be explained because of the unreported sales of one larger company in that area.

Pennsylvania leads all States in the consumption of industrial lubricating oils, using 1,628,245 barrels. Pennsylvania and the other leading industrial States of New Jersey, Ohio, Texas, New York, Illinois, Michigan and California consumed 63 percent of the total. In 1939 these States produced 60 percent of the value of all manufactured goods[2] and in 1947 employed 57.9 percent of the people employed in all manufacturing in the United States.[3] Texas' consumption of 7.76 percent of the country's total industrial oils is considerably on the high side when compared to its share of industrial employment.

Illinois reported the highest consumption, 775,925 barrels, of other

industrial oils. This amount plus that consumed by Pennsylvania, Michigan, California, New York, Massachusetts, Indiana and Missouri make up 71.8 percent of the total market for these oils.

Kinds of Oils and Greases Included Under "Other Oils and Greases"

Absorbent, absorber, absorption oils
Air filter oils
Antirust oils and *compounds
Apron dressings
Batching oils
Battery oils
Brick oils
Cable oils
Coal spray oils (if from lubricants stock oils)
Cordage oils
Core oils
Denaturing oils
Fiber processing oils
Flotation oils
Fogging oils
Form oils and *compounds
Fruit and vegetable preservatives
Heat transfer oils
Ink oils
White oil
*Belt dressings
*Defoamants (Chemical)
Mineral seal oil
Petrolatum Oils
Polishing oils
Insecticides } if primarily of lubricating oil base oils
Larvacides }

*Launching grease — base and slip coats
Magnoflux fluids
Paint and putty oils
Paper processing oils
Petroleum sulfonates
Quartz and glass testing oils
Quenching and tempering oils
Rub-roll oils
Rust-preventative oils and *compounds
Spray oils
Solvents for cleaning lubricating systems
*Tanners products
Textile processing oils
Transformer oils and *greases
Wax oils and emulsions
*Wetting agents
White oil substitute
Wood preservatives
Storm oils
Switch oils
*Water softeners
*Rust inhibitors (Chemical)

*To be reported as greases.

[1] "Lubricating Oil Improvers," paper presented by A. Bruce Boehm at the Division of Marketing Group Session on "Lubrication," Twenty-eighth Annual Meeting of the American Petroleum Institute, November 10, 1948. Published in full in **The Oil and Gas Journal**, November 11, 1948, p. 335.

[2] Census of Manufactures, Bureau of the Census, U. S. Department of Commerce.

[3] Estimates of total employment in manufacturing industries by State, 1947. United States Department of Labor.

SALES OF LUBRICATING OILS AND GREASES, 1947, BY STATES AND BY TYPES

(42-Gallon Barrels)

State	Automotive		Aviation		Industrial Products				Total		Total oils and greases
					Lubricating		Other				
	Oils	Greases	Oils	Greases	Oils	Greases	Oils	Greases	Oils	Greases	
Alabama	254,267	27,354	2,332	70	160,184	18,764	14,261	231	431,044	46,419	477,46
Arizona	77,956	8,805	4,838	5	19,174	2,880	1,200	96	103,168	11,786	114,95
Arkansas	215,100	24,228	1,069	....	74,334	5,158	14,658	39	305,161	29,425	334,58
California	1,278,844	121,209	51,392	224	443,436	44,589	325,797	7,885	2,099,469	173,907	2,273,37
Colorado	158,358	18,645	3,746	....	45,096	5,493	20,548	156	227,748	24,294	252,04
Connecticut	208,950	13,017	8,059	50	156,757	15,775	73,740	12,145	477,506	40,987	488,49
Delaware	36,667	3,214	246	2	15,001	480	16,014	487	67,928	4,183	72,11
District of Columbia	71,765	4,332	2,335	1	21,566	1,030	5,971	480	101,637	5,843	107,48
Florida	341,110	32,004	16,244	12	133,731	4,296	59,670	1,196	550,755	37,508	588,26
Georgia	353,769	38,497	4,334	....	107,099	8,744	54,864	5,093	520,066	52,334	572,40
Idaho	81,105	8,974	94	1	12,389	3,572	6,343	5,011	99,931	17,558	117,48
Illinois	983,416	99,149	10,058	20	688,503	47,988	755,925	23,720	2,457,902	170,877	2,628,77
Indiana	544,646	51,002	3,074	5	258,285	29,912	197,223	7,575	1,003,228	88,494	1,091,72
Iowa	455,895	45,579	729	7	130,195	14,174	39,928	7,754	626.747	67,514	694,26
Kansas	465,622	44,848	2,270	13	114,396	6,858	19,247	6,703	601,535	58,422	659,95
Kentucky	303,200	21,865	1,373	4	123,864	16,028	72,377	192	500,814	38,089	538,90
Louisiana	556,454	26,529	3,339	....	285,736	14,300	32,414	1,384	877,943	42,213	920,15
Maine	117,309	7,868	401	....	30,081	3,250	16,195	10,112	163,986	21,230	185,21
Maryland	359,168	21,611	3,097	1	180,832	20,031	32,984	6,250	576,081	47,893	623,97
Massachusetts	363,427	21,470	4,028	7	219,617	11,727	266,935	16,758	854,007	49,962	903,96
Michigan	893,271	102,995	4,424	41	607,898	24,645	432,100	13,379	1,937,693	141,060	2,078,75
Minnesota	459,529	68,302	4,040	16	146,365	18,921	44,164	3,791	654,098	91,030	745,12
Mississippi	209,564	21,837	1,165	....	41,414	4,217	43,867	101	296,010	26,155	322,16
Missouri	523,951	59,588	5,885	21	169,386	12,192	176,610	8,086	875,832	79,887	955,71
Montana	106,684	13,397	410	2	18,956	2,419	4,643	54	130,693	15,872	146,56
Nebraska	210,967	25,394	1,446	2	67,362	6,159	8,403	211	288,178	31,766	319,94
Nevada	21,750	2,498	114	2	29,816	524	1,360	8	53,040	3,032	56,07
New Hampshire	61,493	3,489	173	2	15,867	811	11,037	5,046	88,570	9,348	97,91
New Jersey	612,339	24,852	12,487	27	995,205	15,054	243,015	12,325	1,863,046	52,258	1,915,30
New Mexico	98,135	10,507	1,121	....	18,271	1,217	714	22	118,241	11,746	129,98
New York	1,230,060	321,827	28,649	88	764,805	36,295	355,256	19,720	2,378,770	377,930	2,756,70
North Carolina	424,534	34,659	1,394	1	87,962	9,171	23,709	5,453	537,599	49,284	586,88
North Dakota	135,851	21,909	413	1	6,056	471	2,390	617	144,710	22,998	167,70
Ohio	1,014,442	85,644	5,724	43	879,277	58,766	385,011	15,756	2,284,454	160,209	2,444,66
Oklahoma	406,195	56,197	6,032	2	220,414	4,438	16,147	1,527	648,788	62,164	710,95
Oregon	204,456	18,599	1,528	6	47,965	6,078	27,696	5,117	281,645	29,800	311,44
Pennsylvania	1,158,031	72,478	11,124	5	1,628,245	124,143	487,164	28,048	3,284,564	224,674	3,509,23
Rhode Island	137,663	5,176	414	1	47,964	1,570	19,630	5,526	205,671	12,273	217,94
South Carolina	222,884	17,307	636	2	44,827	6,484	11,080	6,040	279,427	29,833	309,26
South Dakota	115,140	17,467	428	1	7,330	908	3,821	197	126,719	18,573	145,29
Tennessee	332,004	31,831	3,155	1	102,305	11,956	49,970	79	487,434	43,867	531,30
Texas	1,403,704	130,359	19,651	11	838,528	28,005	50,351	3,566	2,312,234	161,941	2,474,17
Utah	63,386	6,625	1,006	....	25,324	2,876	29,537	89	124,253	9,590	133,84
Vermont	48,692	3,659	99	1	12,281	984	13,501	5,341	74,573	9,985	84,55
Virginia	368,281	29,188	14,678	1	199,526	15,418	31,699	6,529	614,184	51,136	665,320
Washington	248,589	22,031	6,234	14	69,670	8,067	27,432	5,599	351,925	35,711	387,63
West Virginia	161,463	18,714	322	1	277,852	27,239	52,853	2,389	492,490	48,343	540,83
Wisconsin	423,129	48,838	1,400	28	197,434	17,062	169,441	9,373	791,404	75,301	866,70
Wyoming	50,195	5,816	882	....	19,825	3,151	10,120	26	81,022	8,993	90,01
Total, United States	18,578,410	1,921,383	258,092	742	10,808,406	724,290	4,779,015	277,282	34,423,923	2,923,697	37,347,62
Exports*	5,125,579	303,032	396,887	3,848	5,914,546	226,933	911,926	90,540	12,348,938	624,353	12,973,29
Grand total	23,703,989	2,224,415	654,979	4,590	16,722,952	951,223	5,690,941	367,822	46,772,861	3,548,050	50,320,91

*Total of shipments made to destinations outside continental United States, including those to United States Territories (Puerto Rico, Hawaii, Alaska, Panama Canal Zone, etc.)

SALES OF LUBRICATING OILS AND GREASES, 1947, BY STATES AND BY TYPES

(Percentage of United States total)

State	Automotive		Aviation		Industrial Products: Lubricating		Industrial Products: Other		Total		Total oils and greases
	Oils	Greases	Oils	Greases	Oils	Greases	Oils	Greases	Oils	Greases	
Alabama	1.37	1.42	.90	9.44	1.48	2.59	.30	.08	1.25	1.69	1.28
Arizona	.42	.46	1.87	.67	.18	.39	.03	.03	.30	.40	.31
Arkansas	1.16	1.26	.41	....	.69	.71	.31	.01	.89	1.00	.90
California	6.88	6.32	19.91	30.18	4.10	6.16	6.82	2.84	6.10	5.95	6.09
Colorado	.85	.97	1.45	....	.42	.76	.43	.06	.66	.83	.67
Connecticut	1.12	.68	3.12	6.74	1.45	2.18	1.54	4.38	1.30	1.40	1.31
Delaware	.20	.17	.10	.27	.14	.07	.34	.18	.20	.14	.19
District of Columbia	.39	.23	.90	.13	.20	.14	.12	.18	.30	.20	.29
Florida	1.84	1.67	6.29	1.62	1.24	.59	1.25	.43	1.60	1.27	1.57
Georgia	1.90	2.00	1.68	....	.99	1.21	1.15	1.84	1.51	1.78	1.53
Idaho	.44	.47	.04	.13	.11	.49	.13	1.82	.29	.60	.31
Illinois	5.29	5.16	3.90	2.71	6.37	6.63	16.24	8.55	7.14	5.84	7.04
Indiana	2.93	2.65	1.19	.67	2.39	4.13	4.13	2.73	2.91	3.03	2.92
Iowa	2.45	2.37	.28	.94	1.20	1.96	.84	2.80	1.82	2.30	1.86
Kansas	2.51	2.33	.88	1.75	1.06	.95	.40	2.42	1.75	2.00	1.77
Kentucky	1.63	1.14	.53	.54	1.15	2.21	1.51	.07	1.45	1.30	1.44
Louisiana	3.00	1.38	1.29	....	2.65	1.97	.68	.50	2.55	1.44	2.46
Maine	.63	.41	.16	....	.28	.45	.34	3.65	.48	.73	.50
Maryland	1.93	1.12	1.21	.13	1.67	2.77	.69	2.25	1.67	1.64	1.67
Massachusetts	1.96	1.12	1.56	.94	2.03	1.62	5.59	6.03	2.48	1.71	2.42
Michigan	4.81	5.36	1.71	5.54	5.62	3.40	9.04	4.83	5.63	4.82	5.57
Minnesota	247	3.56	1.57	2.16	1.35	2.61	.92	1.37	1.90	3.11	2.00
Mississippi	1.13	1.14	.45	....	.38	.58	.92	.04	.86	.88	.86
Missouri	2.82	3.10	2.28	2.84	1.57	1.68	3.70	2.92	2.54	2.73	2.56
Montana	.57	.70	.16	.27	.18	.33	.10	.02	.38	.54	.39
Nebraska	1.14	1.32	.56	.27	.62	.85	.18	.08	.84	1.09	.86
Nevada	.12	.13	.04	.27	.28	.07	.03	(a)	.15	.10	.15
New Hampshire	.33	.18	.07	.27	.15	.11	.23	1.82	.26	.32	.26
New Jersey	3.30	1.29	4.84	3.64	9.21	2.07	5.09	4.44	5.41	1.79	5.13
New Mexico	.53	.55	.43	....	.17	.17	.01	.01	.34	.40	.35
New York	6.62	16.75	11.10	11.86	7.08	5.01	7.43	7.11	6.91	12.93	7.38
North Carolina	2.29	1.80	.54	.13	.81	1.27	.50	1.96	1.56	1.68	1.57
North Dakota	.73	1.14	.16	.13	.06	.07	.05	.22	.42	.78	.45
Ohio	5.46	4.46	2.22	5.81	8.14	8.11	8.05	5.68	6.64	5.48	6.55
Oklahoma	2.19	2.92	2.34	.27	2.04	.61	.34	.55	1.88	2.13	1.90
Oregon	1.10	.97	.59	.81	.44	.84	.58	1.85	.82	1.02	.83
Pennsylvania	6.23	3.77	4.32	.67	15.06	17.14	10.18	10.11	9.54	7.68	9.40
Rhode Island	.74	.27	.16	.13	.44	.22	.41	1.99	.60	.42	.58
South Carolina	1.20	.90	.25	.27	.41	.90	.23	2.18	.81	1.02	.83
South Dakota	.62	.91	.17	.13	.07	.13	.08	.07	.37	.64	.39
Tennessee	1.78	1.66	1.22	.13	.95	1.65	1.05	.03	1.42	1.50	1.42
Texas	7.55	6.78	7.61	1.48	7.76	3.87	1.05	1.29	6.72	5.54	6.62
Utah	.37	.34	.39	....	.23	.39	.62	.03	.36	.33	.36
Vermont	.26	.19	.04	.13	.11	.14	.28	1.93	.22	.34	.23
Virginia	1.98	1.52	5.69	.13	1.85	2.13	.66	2.35	1.78	1.75	1.78
Washington	1.34	1.15	2.42	1.89	.64	1.11	.57	2.02	1.02	1.22	1.04
West Virginia	.87	.97	.12	.13	2.57	3.76	1.11	.86	1.43	1.65	1.45
Wisconsin	2.28	2.54	.54	3.78	1.83	2.36	3.54	3.38	2.30	2.56	2.32
Wyoming	.27	.30	.34	....	.18	.44	.21	.01	.24	.30	.24
Total, United States	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

(a) Less than .01.

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